DEFENCE R&D DÉFENSE

Development of a Biofidelic Headform for mTBI Assessment,

Experimental and Numerical Analyses

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Defence Military Research Symposium

June 21, 2012
Ottawa

Recherche et développement pour la défense Canada Defence Research and Development Canada

Canada

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
21 JUN 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Development of a Biofidelic Headform for mTBI Assessment, Experimental and Numerical Analyses	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence R&D Canada - Valcartier,2459 Pie-XI Blvd North,Quebec (Quebec) G3J 1X5 Canada,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
DRDC-VALCARTIER-SL-2012-248

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**21**	

Introduction

- Incidence of brain injuries has apparently increased significantly during recent conflicts
  - This might be due to improved body armour that enhances soldier survivability in events that would have been fatal in previous conflicts,
  - The changed nature of combat and associated threats.
- The sequelae of mTBI can be devastating, with survivors experiencing chronic headaches, sensitivity to light or noise, impaired memory, loss in problem-solving abilities, and other significant cognitive and behavioural changes.
- A strong hypothetical cause of the mTBI appears to be the frequent and repetitive exposure of military personnel and first responders to shock and blast loading conditions and as such has recently became a subject of research interest in defence.
- Understandably, current combat helmets, designed to defeat ballistic threats and to attenuate low level impacts, may not protect adequately against blast weapons.

1- Wagner, C., "Brain injuries high among Iraq casualties", ARNEWS, Army News Services, November 24, 2003
2- Jontz, S., "More head injuries in Afghanistan, Iraq push improvements in protective gear", Stars and Stripes, January 30, 2004.
3- Amburn, B., "Brain injuries lead Iraq war injuries", United Press International, July 23, 2004
4- Jaffe, G., "An Army Surgeon Says New Helmet Doesn't Fit Iraq", The Wall Street Journal, August 25, 2004
5- Okie, S., "Traumatic Brain Injury in the War Zone", N. Engl. J. Med., 335:20, pp. 2043-2047, May 2005

Objectives

- The purpose of the *Development of a Novel Biofidelic Headform for Blast-Induced Brain Trauma Assessment* is to develop a test device to evaluate headgear performance against blast loading
- Specific objectives include:
  - Build a finite element model of a human head and the headform,
  - Develop a biofidelic headform and characterize/validate its response where possible,
  - Apply the new tools to preliminary numerical and experimental evaluations of various helmet designs in mitigating the blast-induced TBI.

Outcomes

- Help designers to develop efficient headgear to protect against blast threats.
- Assist in countering more efficiently emerging military, law enforcement and counter-terrorism threats by providing systems with increased blast mitigation capability to end-users.
- Provide valuable information for future test performance standards on multi-threat headgear.
- Provide a novel test method and a test device suitable to evaluate the performance of headgear against blast loading.

Head forms Used In Blast Testing

- Several test head forms have been used for the assessment of blast loading in blast testing. However, none of the head forms possess the capability to measure shockwave propagation through the brain.

Hybrid III headform was developed by GM and used in automotive occupant safety

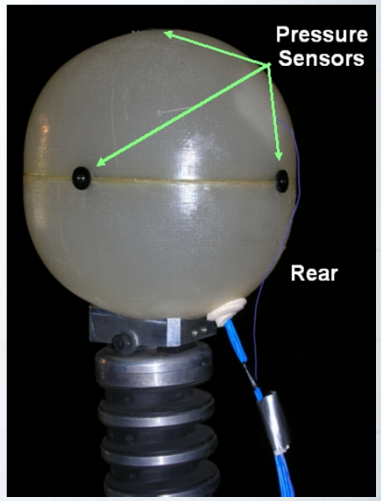
MABIL headform was developed by DRDC and used in blast trials

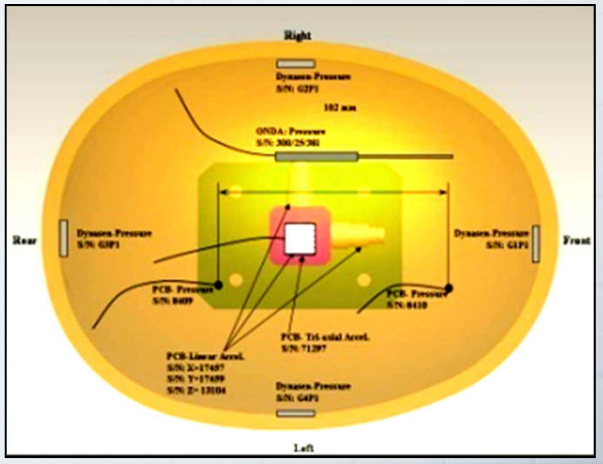
DERAman headform was developed by Britain's Defence Evaluation and Research Agency for blast trials

First Prototype, *Mark 0.5*

- The primary objective behind the Mk0.5 headform was:
  - Identify and evaluate durability of skull and brain materials,
  - Sort out manufacturing issues for the skull and brain,
  - Assess the performance of the preliminary selection of measurement transducers.

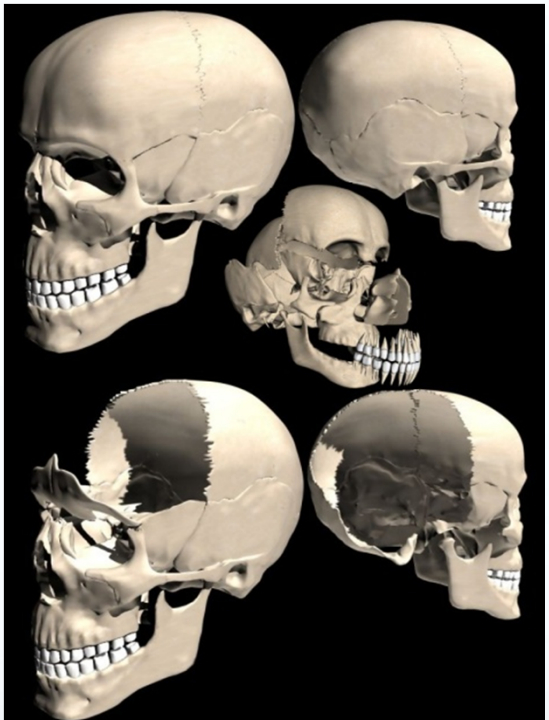
- Numerical simulation was conducted in parallel to the experimental work.



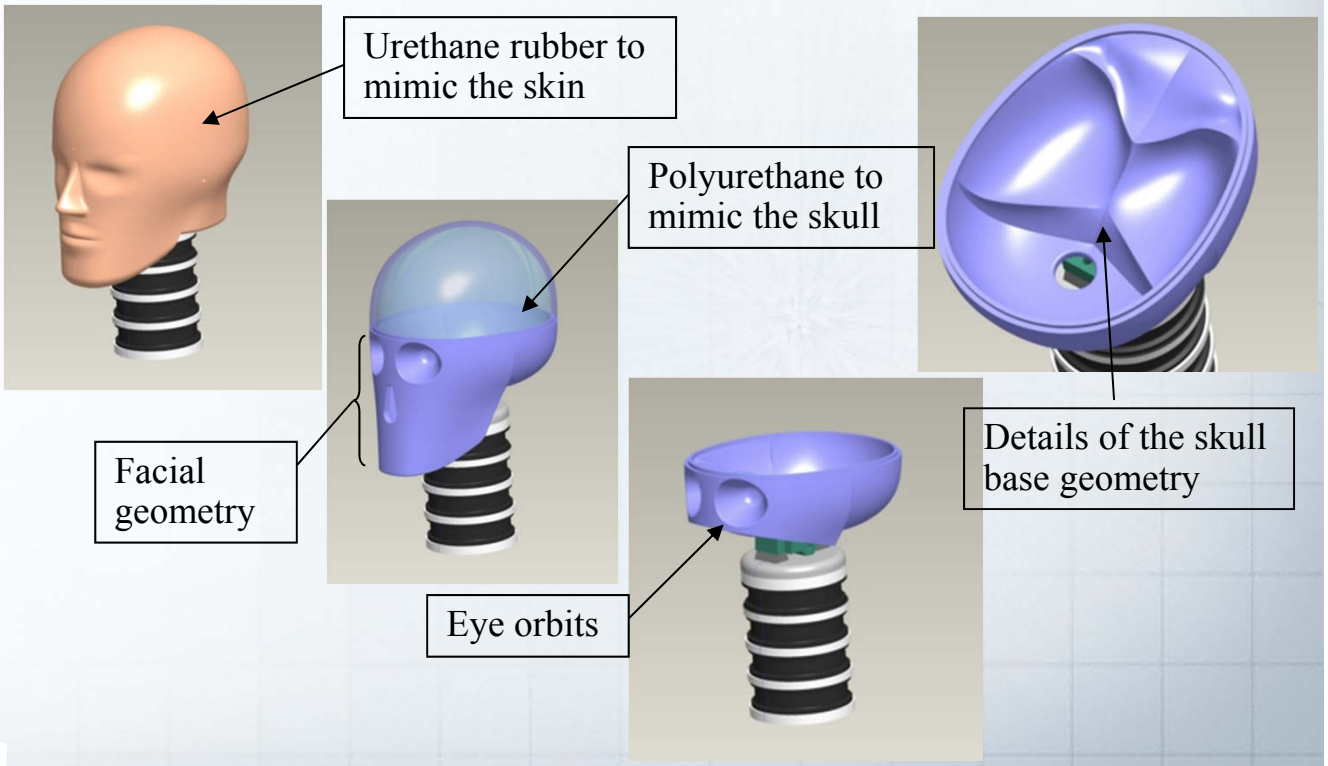


2nd Prototype, *Mark 1*

- The geometry of the upper hemisphere of Mk 0.5 (ISO-J) was carried forward into the Mk 1.
- The geometry below the reference plane was redefined by incorporating anthropomorphic features.
  - Only features that were deemed to have a significant effect on measured load transmission were included

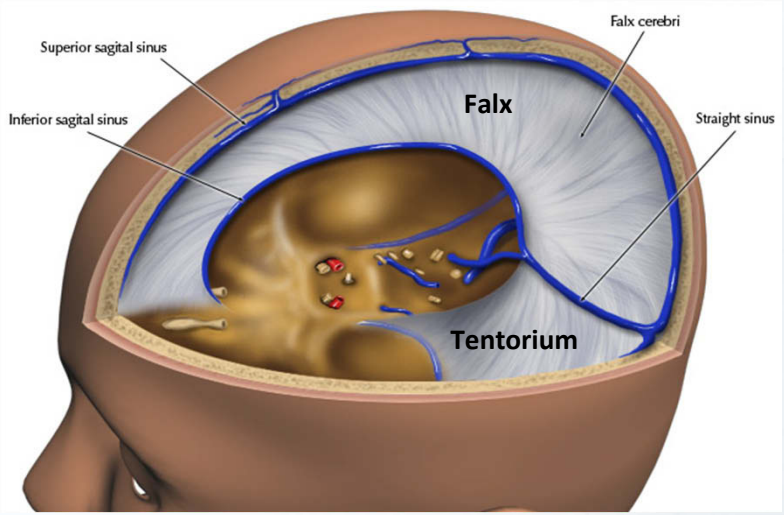


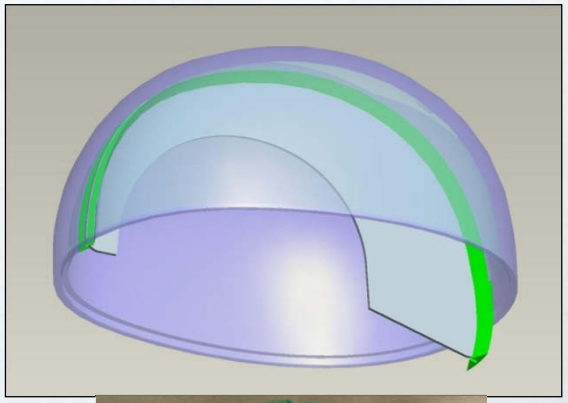
http://www.anatomium.com/3dskull.html



3rd Prototype, *Mark 2*

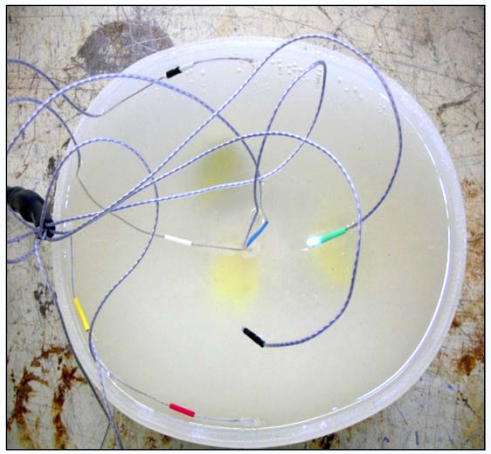
- The overall headform geometry did not change from Mk 1 headform except the addition of :
  - Tentorium and falx membrane,
  - Cerebral spinal fluid between the brain and the skull.

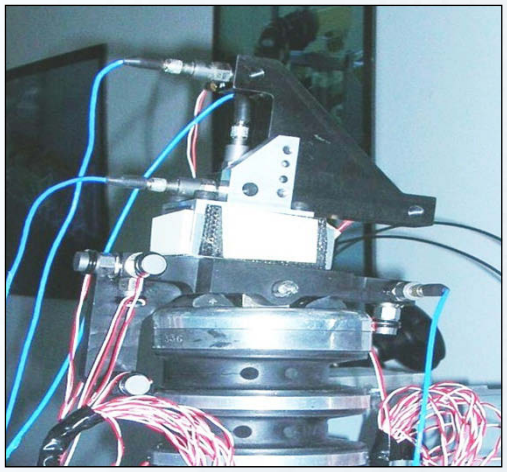


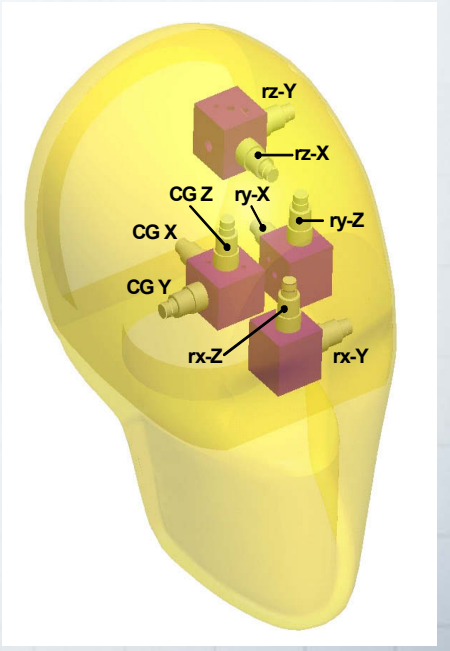


Transducers for Measuring Headform Response

- Different types of transducers were tested with the Mark0.5 and Mark1 headforms:
  - Sonomicrometry (using piezoelectric crystals for strain), Pressure and force Sensor, Hydrophone, Linear and Tri-axial Accelerometers,
  - Different location inside the headform.



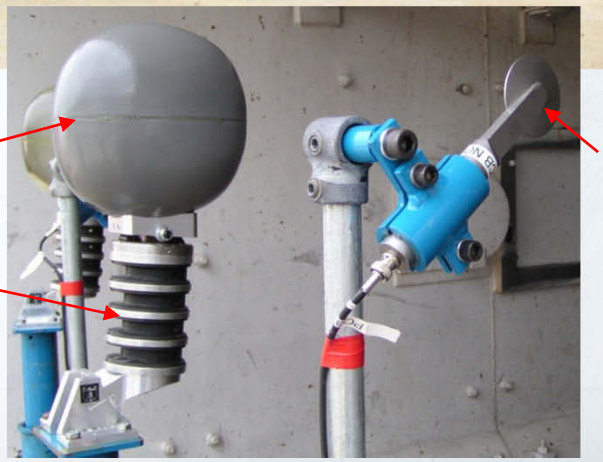




Blast Headform Testing Programs

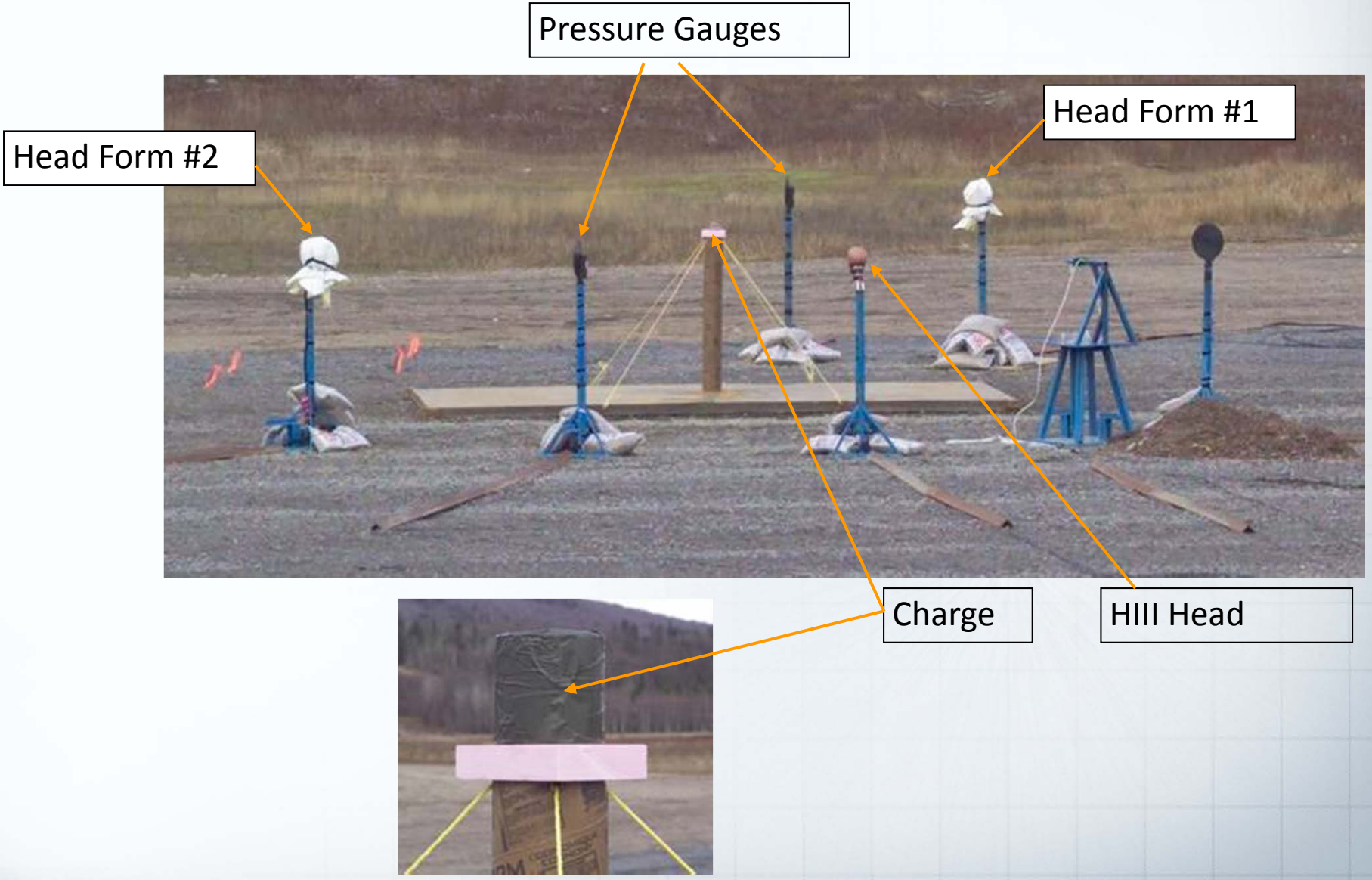
- Different sites to due experimental tests:
  - Blast chamber,
  - Detonic bay,
  - Blast trial.

Detonic Bay Testing, *Small charges*



Detonic Bay Testing, *Video*

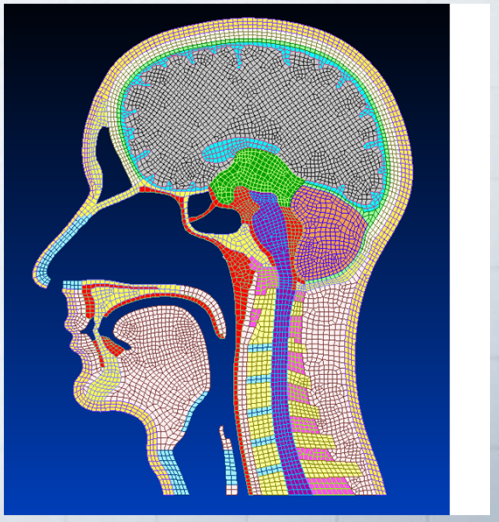
Free Filed Trials, *Large charges*

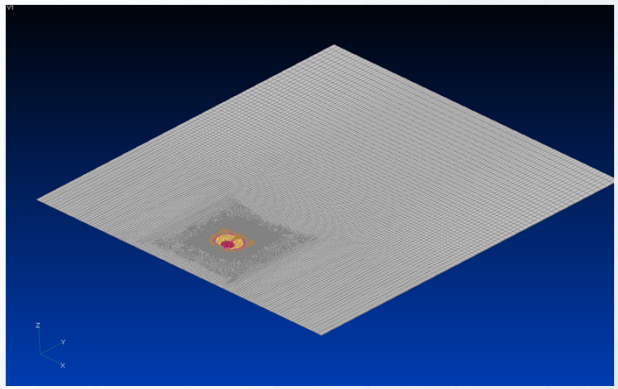


Free Filed Trials, *Large charges*

Numerical Modelling, *Study of blast injury*

- Investigate traumatic brain injuries using advanced numerical modeling
- Coupled ALE (blast wave) and head cross-section analysis
- Correlate response to trauma at a local level
  - Better understand injury mechanisms
  - Design efficient protection

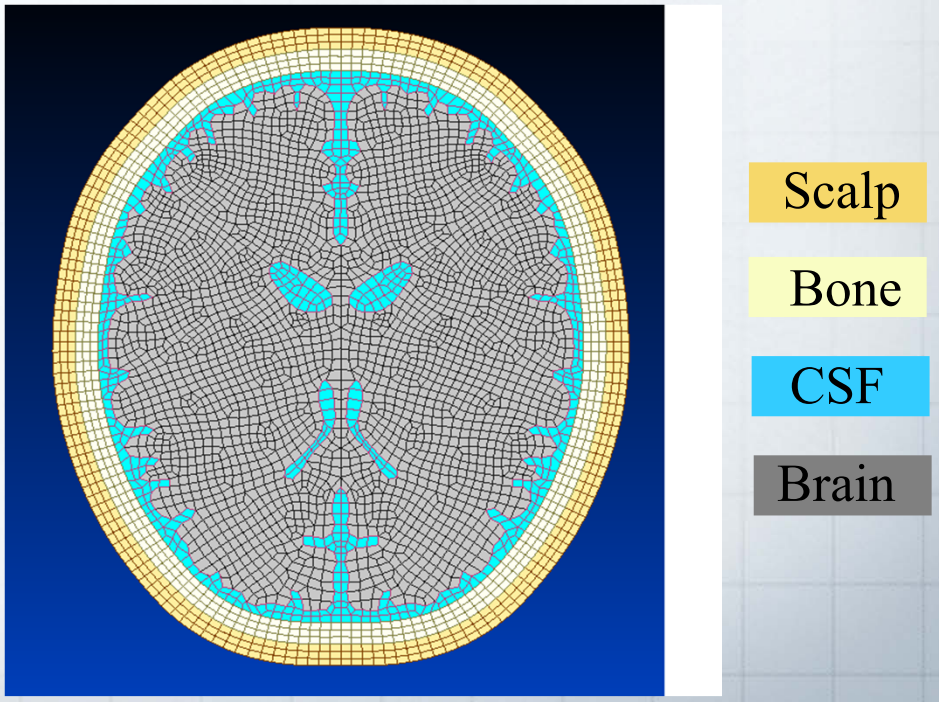




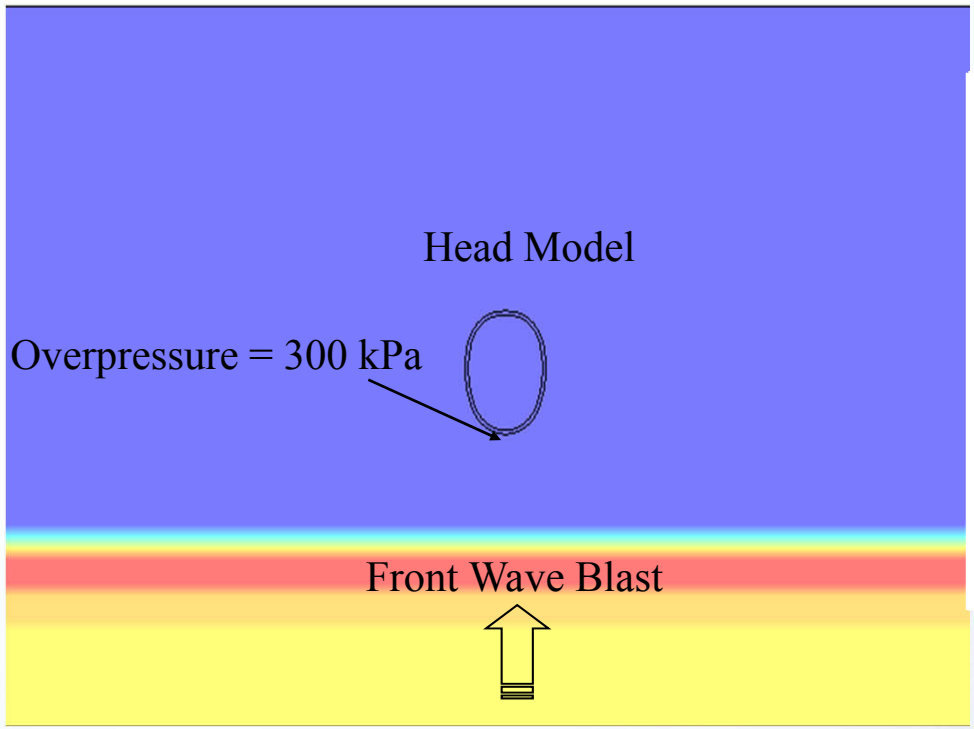
Visible Human Project, National Library of Medicine

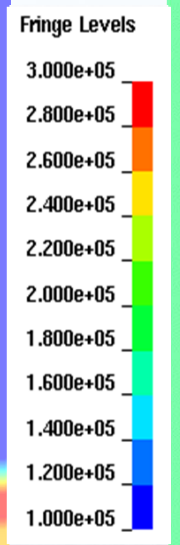
Numerical Modeling, *Mk0.5*

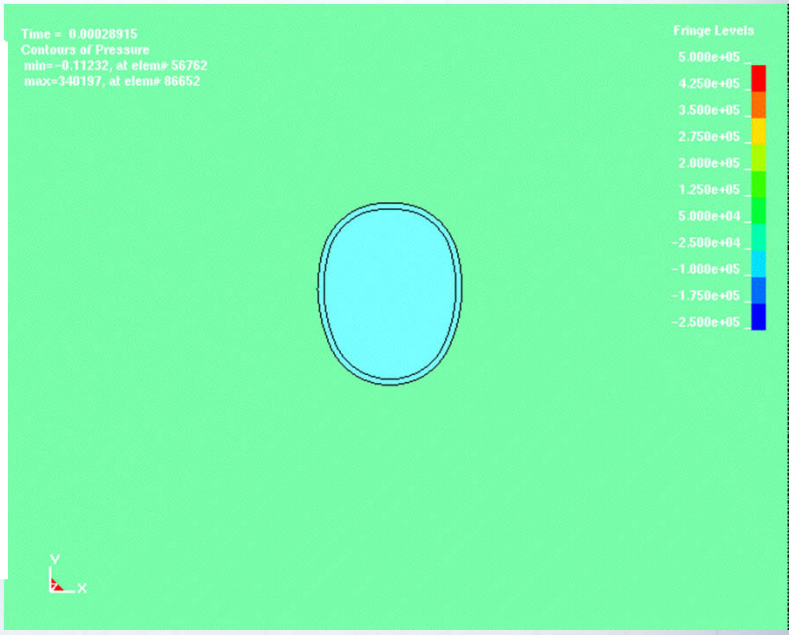
- A fully coupled fluid structure ALE algorithm in the LS-DYNA finite element code is used to model the head and the fluid (air) around it
- Pseudo 2D slice models were used since a full 3D model of the head/surrogate would be computationally prohibitive to implement in the detail needed to track shock propagation
- Pressure loading pulse supplied by ambient elements which can prescribe a pressure time input
- Explored effects of adding/ removing structural details (e.g. CSF, folds in the brain tissue, etc.) on predicted load transmission to the brain



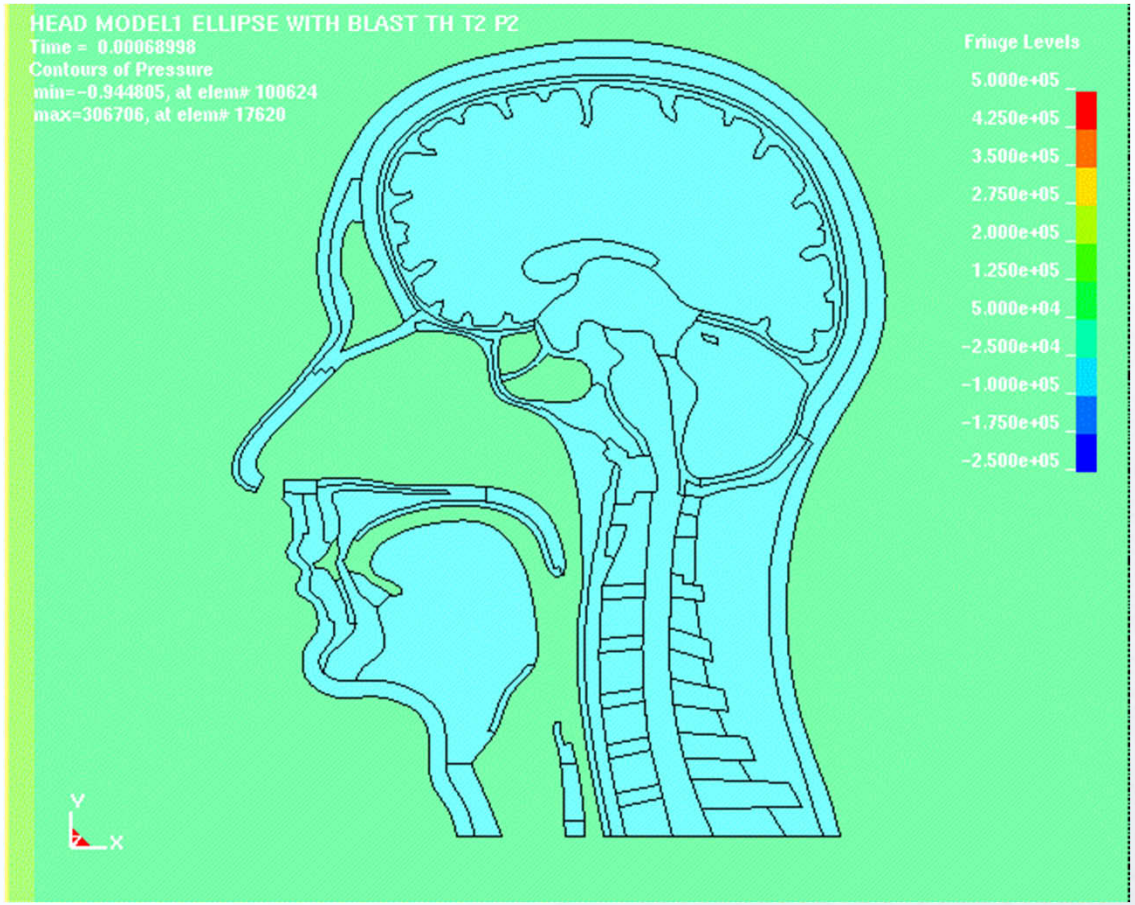
Numerical Modeling, *Mk0.5*







Numerical Modeling, *Sagittal section*



Comparison Between Experimental and Numerical Measurements of Mk 0.5

Conclusion

- A new headform was developed to include geometrical properties of the human skull and the soft tissue of the brain
- The development of the blast headform relied on the limited information available in the literature pertaining to blast injury and injury mechanisms for the CNS
- Material properties and EOS for finite element modelling are limited and do not include high strain rate effect
- Various measurement transducers were evaluated in full scale blast tests.
- COTS sensors fill some but not all the requirements so more work is required in the area of instrumentation
- The information gained was incorporated into a proof of concept surrogate headform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